A method and a system for detecting communication relaying network elements

The present invention refers to a method for detecting communication relaying network elements in cellular communication networks as stated in the preamble of the appended independent claim 1. The present invention also refers to a system for detecting communication relaying network elements in cellular communication networks as stated in the preamble of the appended independent claim 13. Further the present invention also refers to a network element for cellular communication network as stated in the preamble of the appended independent claim 18.

To offer better services to their customers the operators of cellular communication networks are placing increasing numbers of base stations or Base Transceiver Stations (BTS) inside buildings, so that customers using their mobile phones and other mobile communication equipment have acceptable quality of service also indoors. It is quite typical to configure these indoor base stations so that a cell covering only one floor or even a single room of a building is formed. The cells used in cellular communication networks are classified as macro-, micro- and even picocells according to the size of the coverage area of a cell. The size of indoor cells mentioned above are typically under 100 m placing them in the microcell category.

In figure 1a a floor plan 10 of a typical office building is shown. A base station 11 is placed inside the building so that a micro cell consisting three sectors 12a, 12b and 12c is formed.

As there are typically many walls and other obstacles that hinder the propagation of electromagnetic waves inside a building, dead zones, like the zone 13 shown in figure 1a, are formed. A mobile station 16 in a dead zone 13 can not establish communication with the base station 11 or even if the connection can be made, the quality of the connection is poor. To eliminate these dead zones, radio repeaters that are used as relay stations between the mobile station 16 and the base station 11, are placed in locations where they can receive the communication from the mobile station 16 in a dead zone 13 of a base station 11 and where they can relay these communications to the base station 11. Naturally communications from the base station to the mobile station can also be carried out with similar fashion.

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In figure 1b a floor plan identical to the floor plan in figure 1a is shown. However, in figure 1b a radio repeater 14 is placed so that the coverage area 15 of the radio repeater 14 covers the dead zone 13 of the base station 11, shown in figure 1a.

In figure 2 it is shown how a mobile station 21b, situated behind an obstacle 22 in a dead zone of the base station 11 communicates with the base station 11 via a radio repeater 14. When a mobile station 21b is used, the radio repeater 14 receives the communication and transmits it to the base station 11, typically using the same channel, although in some cases the use of channel changing radio repeaters are preferred. Accordingly the communication from the base station 11 is relayed via the radio repeater 14 to the mobile station 21b. Communications between the base station 11 and a second mobile station 21a that is within the coverage area of the base station are performed directly without radio repeater 14.

A basic radio repeater consists of a receiving and a transmitting section with at least two antennas, one covering the dead zone of the base station and another to carry out the communication with the base station. A typical use of radio repeaters is just to relay the received communications in a same channel, both downlink from the base stations to the mobile station and uplink from the mobile station to the base station. For economical reasons there is no sophisticated monitoring equipment usually included in the radio repeaters. Therefore in the prior art there is no way of getting any information about the operation of the radio repeaters to the network management system. This can cause situations where a radio repeater can be out of operation without the operator knowing it before receiving complaints from customers who have noticed that they have a dead zone in some area.

For the man skilled in the art an obvious solution to get more information about the function of radio repeaters would be to include sophisticated monitoring equipment in a radio repeater. This equipment could then be connected directly or through the base station to the network management system. This solution would however mean a considerable increase in the manufacturing cost of the radio repeater.

The document WO 96/07250 describes various problems and arrangements regarding repeaters. However, those arrangements do not provide solutions for the present problems.

An object of the present invention is to provide a new method for detecting communication relaying network elements, like radio repeaters. The method can be utilised without any monitoring equipment in the element itself thus eliminating the above stated problems of the prior art.

A further object of the present invention is to provide a new system for detecting communication relaying network elements, like radio repeaters. The system can be utilised without any monitoring equipment in the element itself.

A further object of the present invention is to provide a new network element comprising a system for detecting communication relaying network elements, like radio repeaters. Current network elements can be converted to the network elements according the invention with software modifications making the conversion easy and economically feasible.

The above stated objects are achieved by monitoring the time delay between a mobile station and a base station to determine if the communication is relayed via at least one relay element or performed directly with the base station. The communications from a mobile station performed via at least one relay element are detected by the increase of time delay compared to the time delay of mobile stations communicating directly with the base station.

More specifically the above stated objects are achieved by the means of a method, a system and a network element which are characterised by what is stated in the characterizing portions of the appended independent claims 1, 13 and 18. Preferred embodiment of the invention are described in dependent claims.

Compared to the prior art, the present invention gives significant advantages. When the information coming via a relay element can be recognised, it is possible to get information about the operation of relay elements to the operator, for example through the network management system (NMS). This gives the operator more complete understanding about the network and assists the operator to identify possible problems caused by relay elements, thus enabling the operator to improve the quality of the service offered to the customers.

The present invention is also quite simple and economical to implement to the present cellular networks as there is no need for additional hardware, neither for base station nor to relay elements. The method according the present invention can be implemented with only software modifications to present cellular communications networks.

The present invention will now be described more in detail in the following with the reference to the accompanying drawing, in which

Figs. 1a and 1b show schematically how a dead zone of a base station can be covered with a use of a radio repeater,

Fig. 2 shows schematically the use of radio repeaters in cellular communication networks,

Figs. 3a and 3b show schematically the reception and transmission cycles of GSM-mobile station located close to and far from a base station,

Fig. 4 shows a flow chart of an embodiment of the method according the present invention,

Fig. 5 shows schematically the use of optical tunnelling in cellular communication networks,

Fig. 6 shows a distribution of communications as a function of time delay, and

Figs. 7a and 7b show network elements comprising a system according the present invention.

Figs. 1 and 2 have been discussed above in context of the prior art.

In fig 3a a structure of reception and transmission frames of a GSM mobile station located close to the base station is shown. As stated in the GSM standard the transmission frame 31b has been delayed from the reception frame 31a by three burst periods (BP) [1]. In fact, the convention is that the numbering of the uplink slots (transmission of the mobile station) is derived from that of the downlink (reception of the mobile station) ones by a shift of 3 burst periods [1]. As the transmission and reception of the mobile phone is done with the same slot number, slot 2 in fig. 3a, this allows mobile station to avoid emitting and receiving simultaneously, thereby promoting easier implementation, when the receiver in the mobile station need not be protected from the emitter of the same mobile station.

When the mobile station is far from the base station the propagation delays between a mobile station and a base station are no more negligible compared to the burst duration. As the base station may have to handle communications with several mobile stations simultaneously it is imperative that the bursts from each mobile station are received in correct time slots. Otherwise the bursts coming from different mobile stations could overlap resulting poor transmission quality. This has been solved in present networks by controlling the time delay between the reception and transmission frames of the mobile station. This is done using timing advance (TA).

In figure 3b it is shown how the timing advance is used in determining the time delay between reception and transmission cycles of mobile station. When a base station, a base station controller (BSC) or another entity for determining the timing advance has determined a proper timing advance value for example using methods explained in reference [1] pages 346-349, the timing advance value is sent to the mobile station using methods also known *per se*. When the mobile station receives a timing advance value, it advances the transmission of its transmission slot by the amount indicated by the timing advance value. Therefore, from the point of view of the mobile station the time difference between the downlink frame 31a and the uplink frame 31b is no more three times the burst period (BP), as in fig. 3a, but three times the burst period (BP) minus the timing advance (TA) indicated by the received timing advance value, as in fig 3b.

It is evident from what was explained above that the timing advance is increased, when the propagation delay between the base station and the mobile station is increased. When a mobile station is closer than 500 m to a base station in a GSM network environment the propagation delays between the base station and the mobile station are negligible, resulting in a zero timing advance. This is the case for a mobile station located in a microcell, which are by definition quite small. The situation changes when the communication is relayed via a relay element like a radio repeater in figure 2. The radio repeater causes some delay for the communications between a mobile station and a base station. The base station can observe the presence of a radio repeater from an increase of the timing advance. It is quite typical that timing advance of a mobile station communicating with the base station via a radio repeater will correspond to a timing advance caused by a distance of several kilometres. In a microcell environment where maximum actual distances where mobile station can be situated and still be able to communicate with the base station is typically only a few hundred meters. Therefore it is possible to use the timing advance value for determining if the communication between a mobile station and a base station is performed via a radio repeater or any other delay causing network elements.

In fig 4 a flow chart of an embodiment of a method according the present invention is presented. In the step 41 a base transceiver station (BTS) receives a transmission transmitted by a mobile station. This transmission is in typically a burst containing digitised information, like in GSM networks. The burst can be normal data burst, an access burst or any other kind of information that can be used to determine the timing advance of a mobile station.

In the step 42 the timing advance (TA) is determined by a base transceiver station, a base station controller (BSC), or another entity which determines the timing advance. Timing advance can be expressed in microseconds or a timing advance value with an integer value (typically 0-63 in GSM networks) corresponding to the actual timing advance.

In the step 43 it is determined if the timing advance is greater that the maximum timing advance possible for a mobile station situated in the coverage area of the base station and communicating directly with the base station. In a microcell in a GSM network this can usually be done quite simply as the timing advance values for all mobile stations communicating directly with the base station are zero, thus simplifying the step 43 only to the checking of the timing advance value already calculated in step 42. If the timing advance value is greater than zero then the communication is judged in step 44 to be coming via a delay causing relay element, like a radio repeater. In some advantageous embodiments of the invention, even the identification of the relay elements is carried out in step 44 using the method to be described in context of fig.6.

If the timing advance value is equal to zero, it is concluded in step 49 that the mobile station is communicating directly with the base station.

When it has been concluded in step 44 that the communication is performed via a relay element, this information may be used in many different ways, some of which are included in the flow chart in fig. 4. In the step 45 it is determined if it has been detected before that there is a relay element in that particular cell. If there is no earlier indications about relay elemement in the said cell then in step 46 a notice informing about the presence of a relay element in said cell is sent to the network management system to be included to the data base.

After the notice has been sent in step 46 or if the presence of a relay element was already known, directly after step 45, it is checked in step 47 if there are any particular measurements to be carried out for the communications performed via a relay element. These measurements for example updating performance management counters such as dropped call ratio and hand over failures are then carried out in step 48.

In step 50 normal information processing is carried out for the bursts received in step 41, both for the bursts coming via the relay elementas for the bursts coming

directly from the mobile station. After step 50 it is returned back to the step 41 for receiving a new burst.

The method described above is not limited only to the indoor or microcell use, but can also be used for example in macrocells if a maximum timing advance for a mobile station communicating directly with the base station can be found and a timing advance caused by a relay element is greater than this maximum timing advance. Then the limiting criteria in step 43 in fig. 4 is not limited to that the value is greater than zero, but greater than a some cell specific value.

In fig. 5 another communication relaying network element namely optical tunnelling configuration is shown. With optical tunnelling configuration a coverage area of a base station 11 can be extended to locations that cannot be readily covered with a simple radio repeater. Optical tunnelling configurations are used for example when a coverage area of a base station is extended into two separate buildings.

In optical tunnelling configuration communications between a mobile station 21b and a base station 11 is performed via two receiving/transceiver sections 54a and 54b, two electro-optical converters 52a and 52b, and via optical transfer means 51.

The first receiving/transceiver sections 54a relays communications between the base station 11 and the first electro-optical converter 52a. The first electro-optical converter 52a converts communications received by the first receiving/transceiver sections 54a to optical information and sends the optical information via optical transfers means 51 to the second electro-optical converter 52b. The second electro-optical converter 52b converts received optical information to electrical form and transfers it to the second receiving/transceiver section 54b relaying information to the mobile station 21b. Accordingly communications from the mobile station 21b is relayed via second receiving/transceiver section 54b and second electro-optical converter 52b to optical transfer means 51, where it is received by the first electro-optical converter 52a transferring the information to the first receiving/transceiver sections 54a and further to the base station 11.

Receiving/transceiver sections 54a and 54b and electro-optical converters 52a and 52b cause time delays for the communication between the mobile station 21b and the base station 11. Therefore the present invention can also be used for detection of optical tunnelling configurations.

In figure 6 an example of a distribution of communications in a cell as a function of time delay is shown. The cell has two different relaying elements.The first peak 62

in the distribution is caused by the communications performed directly with the base station. The second peak 63 is caused by the communications performed via the first relay element, for example radio repeater. The third peak 64 is caused by the communications performed via the second relay element, for example optical tunnelling configuration.

In figure 6 the maximum time delay 61a for a mobile station communicating directly with the base station is shorter than the minimum time delay caused by the relay elements. Therefore it can be concluded that communications with time delay in interval A in figure 6 are performed directly with the base station. The maximum time delays 61b and 61c for communications performed via the first and second relay elements are known and the minimum time delay for communication performed via the second relay element is longer that the maximum time delay 61b for communication performed via the first relay element. Therefore in can be concluded that communications having time delay within interval B are performed via the first relay element and those having time delay within interval C are performed via the second relay element.

If the distribution of communications as a function of delay times show a clear multipeak distribution, like in figure 6, the present invention can by used not only to identify that a communication is performed via a relay element, but also to identify the relay elements performing the communication. An analysis of possible time delay intervals for each particular cell should be carried out before making detailed identification of elements, so that the individual characteristics of each cell could be taken into account.

The present invention can also be used for detecting malfunctioning elements. This can be accomplished for example by storing an indication of the existence of a delay every time a delay causing relay element is detected in a cell. Using some monitoring means these indications can then be monitored. When enough time have been passed since a relay element was previously detected in a cell, a notice informing about a possible malfunction in a relay element in that cell can be sent to the operator.

The present invention is not limited only to the examples presented above, but can also be used to detect also any other kind of delay causing network elements. Furthermore the present invention is not limited only to the GSM network, but can be utilised in all kind of cellular communications networks, such as the UMTS network, where timing advance or similar methods are used to compensate the

propagation time delays between a base station and a mobile station. Therefore the actual way of determining the timing advance is not relevant to the present invention.

In fig 7a and 7b two embodiment of a system 70 according the present invention are shown. In figure 7a the system is placed in a Base Station Controller 72 and in 7b the system 70 is placed in a Base Transceiver Station 74. The system 70 has I/O-interface 76 via which the system can communicate with the Network Management system 75 and monitor communications between BTS 74 and mobile stations 21a and 21b. Communication time delays between BTS 74 and mobile stations 21a and 21b are monitored and different relay elements identified by the processor 71. The program 73 saved in the memory 72 is used to control processor 71 so that the relay causing network elements can be detected and possibly identified using the method according the present invention.

The name of a given functional entity, such as the base station controller, is often different in the context of different cellular telecommunication systems. For example, in the UMTS system the functional entity corresponding to a base station controller (BSC) is the radio network controller (RNC). Therefore, the particular terminology used to denote various functional entities in this specification are only examples according to the GSM system, and do not limit the invention in any way.

In view of the foregoing description it will be evident to a person skilled in the art that various modifications may be made within the scope of the invention. While a preferred embodiment of the invention has been described in detail, it should be apparent that many modifications and variations thereto are possible.

REFERENCES:

[1] Michel Mouly, Marie-Bernadette Pautet: "The GSM System for Mobile Communications", ISBN 2-9507190-0-7, Palaiseau 1992.